A number of factors have come together in recent years to increase interest in water recycling in the Anadarko and Permian Basins, such as:
- Water availability
- Induced seismicity
- Limited disposal zones for Class II wells
- Environmental concerns
- Etc

Many options for recycling are being explored.

One basic approach that incorporates holistic water management strategies has proven to be successful and cost effective.

However, there are some keys to success that should be considered.

Source: ALL Consulting, 2016
Drivers for Recycling

- Demand for recycling of produced water in the Permian and Anadarko basins is expanding
- Reduce demand on limited freshwater resources
- Reduce injection volumes
  - Reduce injection costs
  - Limited disposal zones for Class II wells
  - Induced Seismicity concerns
- Reduce costs of fresh water

Source: ALL Consulting, 2016
Water Availability

• Although 2017 hasn’t necessarily been a drought year, the Anadarko and Permian Basins typically experience high or extremely high levels of water stress
  • Permian Basin
    – Surface water sources for completion activities are essentially non-existent
    – Many areas have very productive ground water wells (20 – 50 bbl/min)
  • Anadarko Basin
    – Ground water is typically limited
    – Surface water is the primary source of water for completions (Cimarron River and local streams)
• Many operators are turning to recycling as a way to reduce demands on limited freshwater resources
Water Needs and Costs

• Horizontal wells in these areas may have laterals that are 5,000, to 12,000 ft. long
• Fracture fluid volumes typically range from 500,000 to 1,000,000 bbls – or more!
• Fresh water is expensive
  – In the Permian, costs are running about $0.50 to $0.75 per bbl.
  – In the Anadarko, costs may vary from $0.25 to $0.50 per bbl.
• The costs for many produced water treatment processes may range from $0.25 to $1.00 per bbl.
• These costs are creating even more interest in recycling and in exploring lower cost treatment systems
Disposal Considerations

- A marked increase in seismicity in Oklahoma and elsewhere has resulted in decreases in allowable injection volumes in some areas – especially injection into the Arbuckle. Additionally operators are choosing to find ways to limit injection volumes as a way to prevent seismicity concerns.
- Alternate disposal zones for Class II disposal wells are limited in many areas.
- Trucking produced water for disposal is expensive and can create adverse community impacts.
- In the areas we are working in, produced water volumes typically range from 5,000 to 7,500 bbl/day.
- These challenges have caused many operators to explore recycling as a way to reduce injection volumes.
A Basic Approach that Works

- Combine produced water treatment and UIC disposal at the same facility with multiple facilities strategically placed throughout the acreage
- Separate pipelines to move raw produced water and clean brine between facilities
- Tank battery to remove solids and separate oil
- Treatment system to provide a clean brine
- Injection well for produced water that cannot be recycled
Infrastructure planning
- Plan placement of treatment and disposal facilities to serve the entire acreage
- Practical limit of lay-flat is about 3 miles.
- Install buried HDPE pipelines between facilities

Flexibility
- Need to be able to move both treated and produced water from any treatment and disposal facility to any other.
- Allow for delivery to and from each facility by both truck and pipeline
Tank Batteries

• Located adjacent to an injection well and treatment pits
• Remove solids and separate oil
• Automated to send water either to the injection well or to the treatment pits (or both) based on operator-determined settings such as:
  – Produced water tank levels
  – Desired injection volume
  – Desired flow to treatment pits
• Typically coupled with 2 H-pumps
• H-Pumps controlled by variable speed drives (VSDs)
Treatment System

- The treatment system is simple and consists of:
  - A series of lined impoundments for progressive treatment of produced water
  - Aeration and microbial treatment to remove organics
  - Water moves from impoundment to impoundment via equalization pipes
  - Multiple impoundments improve settling and provide ample storage
- Results in a clean brine suitable for reuse

Source: ALL Consulting, 2016
Impoundments

- Preferred design typically includes 6 lined impoundments
- Impoundment liners consist of:
  - Geotextile layer with gas vent strips
  - Secondary liner (40 mil smooth black geomembrane)
  - Leak detection system
    - Geocomposite layer
    - Sump with washed pea gravel
    - Pipe
  - Primary liner (40 mil textured white geomembrane)
- Impoundments are connected by equalization pipes that can be closed to isolate impoundments if needed
- Suction pipes are installed in the clean brine impoundment
**Additional Considerations**

- During build-out and in the early stages of a drilling program (e.g., when produced water volumes are low) impoundments can be used to store fresh water to support completion operations
  - In some areas, water wells adjacent to the impoundments have been drilled into saline aquifers as a way to support completions while still minimizing fresh water use

- It is important to build out the system early.
  - In the early stages of a drilling program companies may be inclined to delay capital investment in infrastructure by only partially building out facilities and drilling injection wells
  - However, as wells start to come on line, the total produced water volume increases quickly, and can overwhelm the system. This may require installation of temporary treatment systems and/or trucking of produced water to commercial disposal facilities
Benefits of the Approach

- Reduces fresh water demands for completion activities to near zero
- Reduces injection volumes
- Ensures an adequate supply of make-up water for completions
- Provides options for managing produced water (e.g., adjusting injection volumes vs. treatment volumes) based on changes to produced water volumes or unexpected changes in the completion schedule
- Reduces costs
  - Limits trucking for produced water disposal
  - Overall cost of treatment to produce a clean brine is typically $0.15 to $0.25 per bbl
Keys to Success

• Provide a cost-effective holistic approach to water management that allows operators to easily manage produced water through a combination of Class II disposal wells and recycling
• Provide flexibility to respond to unexpected changes in schedules, equipment failures, injection well problems, etc., by being able to easily move water from one facility to another
• Provide flexibility to receive produced water and to distribute clean brine by both pipeline or truck
• Simple operations: automated controls and an uncomplicated treatment system limit operator involvement in day to day operations, with minimal operator training required
• Capital investment costs are typically recovered in three years or less.
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